# Agro-Weather Services in Public-Private Partnership

## LESSONS FROM THE SESAME GROWING ZONES IN NORTH-WEST ETHIOPIA

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Weather Impact, SBN, NMA
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Weather Impact

# Summary

Climate change is impacting on global food production. The risks of crop failure due to climate change-induced weather variability are highest in small-scale agriculture, which is often rain-fed. On the positive side, mobile phones and other new communication technologies offer great opportunities to digitalize agricultural services, especially in remote places. Weather and climate information services are also improving thanks to the widespread availability of satellite data, while web-interfaces, APIs and other IT technology enable easy dissemination of this information.

This article highlights these opportunities and how we have put them into practice in North-West Ethiopia in a public-private partnership of Ethiopian and Dutch partners. Thanks to this partnership, around 10,000 farmers in Ethiopia's sesame-growing area now receive a weather forecasting service on their mobile phone. In this article we share lessons learned from this five-year programme and also our views on improving and sustainably implementing last-mile weather and climate services.

The major lesson learned from this programme is that National Meteorological and Hydrological Services play an essential role in the partner chain of weather services. They are the mandated institution and need to be at the core of the service development. Yet most of these institutes in Africa lack the capacity and financial resources to take on this role. We believe that public-private partnerships have the potential to empower these institutions to take on this challenging task. This article contains practical ideas on how a sustainable partnership can be achieved, with our aim being to share the lessons we learned in Ethiopia:

1. Twice-weekly localized weather forecasts by mobile phone can make an essential difference to farmers' day-to-day farm management;
2. Institutionalization of the service delivery within the National Meteorological Agency and cooperation with other government bodies is necessary to ensure long-term continuity of the services;
3. High-quality, high-quantity local weather data are necessary for validating weather forecasts in Ethiopia's various climatic zones;
4. Global models and cloud IT infrastructure solutions enable efficient delivery of high-quality services;
5. Capacity-building and development are essential for establishing a successful service;
6. Public and private partners can co-create to develop the business case for weather and climate data.

We believe that the experience we gained in Ethiopia has a wider application and so want to share it with initiatives taking place in or planned for other regions and countries. The need to adapt to climate change is a local challenge that is presenting itself across the world. We hope to inspire current and potential new partners to develop local weather information services in sustainable partnership with their National Meteorological and Hydrological Services.

## GLOSSARY

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|---|---|
| Agromet value chain | All the activities and enablers that together create agro-meteorological services, analogous to the "hydromet value chain" introduced by (GFDRR, 2019) |
| Agro-meteo forecast | Weather forecast specifically targeted to the agricultural sector |
| Agro-meteo advice | Farm management recommendations based on operational weather information |
| Amhara | Region in Ethiopia |
| Ensemble forecasting | Technique where a weather model is run several times, with slightly adjusted initial conditions, to generate stochastic or probabilistic forecasts |
| Kebele | Smallest administrative unit in Ethiopia; village, neighbourhood level |
| Hilla | Stack of sesame that is drying in the fields after harvesting |
| NMA | National Meteorological Agency of Ethiopia |
| NMHS | National Meteorological and Hydrological Service(s) |
| NWP | Numerical Weather Prediction (model) |
| PPP / PPE | Public-Private Partnership / Public-Private Engagement |
| SBN | Sesame Business Network |
| Sesame | The crop sesame, *Sesamum indicum*, grown in Ethiopia |
| Tigray | Region in Ethiopia |
| WEnR | Wageningen Environmental Research |
| WI | Weather Impact |
| WMO | World Meteorological Organization |
| Woreda | Indication of districts (third-level administrative divisions) in Ethiopia |

# AGRO-WEATHER SERVICE PARTNERSHIPS

Weather influences almost every aspect of a farming business. From the smallest household garden up to the largest farm on the globe, all these businesses depend on local weather variability for their yields and income. The risks of crop failure due to climate change-induced weather variability are increasing (Smith, et al., 2007). Weather forecasts, seasonal outlooks and climate analyses provide strategic information so that farmers can optimally time their farm management practices.

Today, we are seeing numerous innovations in communication technology, including rapidly expanding mobile phone and internet coverage. These advances mean that mobile phone technology is now becoming available in even the remotest places (GSMA Intelligence, 2019). This creates huge opportunities for digitalizing the agricultural sector around the globe, especially small-scale agriculture in the developing world (Tsan, Totapally, Hailu, & Addom, 2019) (Mensink, Vranken, Boogaard, Noort, & Michael, 2017). The digital ag-tech innovations we are seeing today range from plant-specific spraying schemes performed by drones in large-scale precision agriculture to simple text message (SMS) weather forecasts sent to small-scale farmers by mobile phone. All these services depend on good-quality weather data, derived from historical localized measurements and knowledge and/or from weather and climate forecasts based on numerical models. Good-quality weather data is the first building block in a reliable, high-quality decision-support service for farms.

This chapter discusses weather services. We first highlight the advances achieved over the past 50 years and then explain the concept of the "hydromet (or agromet) value chain". Lastly we use this information to develop a framework for delivering sustainable agro-meteorological services to small-scale farmers.

## Advances in weather services

Reliable weather and climate services require high-quality data on local weather, water and climate conditions. The past 50 years have seen a revolution in weather science: satellites have been launched for observing the atmosphere, land surfaces and oceans; computer capacity is increasing all the time, and weather and climate models have improved tremendously. Ensemble weather forecasting techniques have also been introduced to provide probabilistic information. All these advances in weather science have improved our weather prediction skills, with the result that we can now forecast the weather up to 7 days in advance as accurately as we could up to 4 days in advance 15 years ago. This is a silent revolution that has been taking place gradually.

Another revolution in society has been the shift from the provision of weather services as a purely public task to a society where basically any individual with a smartphone can access an app with

weather information from a non-public source. As a result, there is now a highly active private weather sector providing tailored weather services to businesses and consumers alike.

Fifty years ago, almost all weather information was provided by National Meteorological Services (NMHS),[1] which were the only source of weather-related services in their country. Today, NMHS still form the backbone of countries' weather-related services and should have the capacity to operate and maintain a weather observation network, do basic research and development, run Numerical Weather Prediction (NWP) models and, above all, provide weather information in the form of public forecasts and alerts. NMHS are often also the mandated organizations for providing weather forecasts and official weather warnings in a country.

The public and private sectors share the goal of wanting to develop and deliver high-quality weather services, and the cooperation between these sectors is referred to as the "global weather enterprise" (Thorpe, 2016). The private weather sector generally translates developments in public weather science into added-value solutions that provide socio-economic benefits to customers. As such, it is still highly reliant on advances made by the publicly funded scientific community.

## Developing the agro-meteorological value chain

This article uses the term "agro-meteorological value chain" to describe the whole ecosystem of activities and capacities needed to deliver an agro-meteorological service. This value chain, which is introduced and referred to as the "hydromet value chain" in (GFDRR, 2019), includes all the activities and enablers that together create meteorological services. It comprises the combination of meteorological observations, numerical weather predictions, and the generating of forecasts, issuing of warnings and delivering of tailored business services, as well as all the enabling factors such as institutional capacity, research and development, education and capacity development, and data and ICT infrastructure. As this article focuses on this concept with regard to delivering services to farmers, we refer to it as the agro-meteorological (or agromet) value chain.

Establishing a reliable agromet service requires many enablers and activities. The issuing of official warnings, for example, requires the availability of NWP models, appropriate ICT infrastructure able to run the models, well-educated staff to operate the models and interpret the results, and a communications network to issue the warnings, etc.

Figure 1 shows an example of a partner chain in an agro-meteorological service for small-scale farmers, demonstrating all the different activities, enablers and roles needed in such a service.

[1] As this is often combined with hydrological services, we use the acronym 'NMHS': National Meteorological and Hydrological Services.

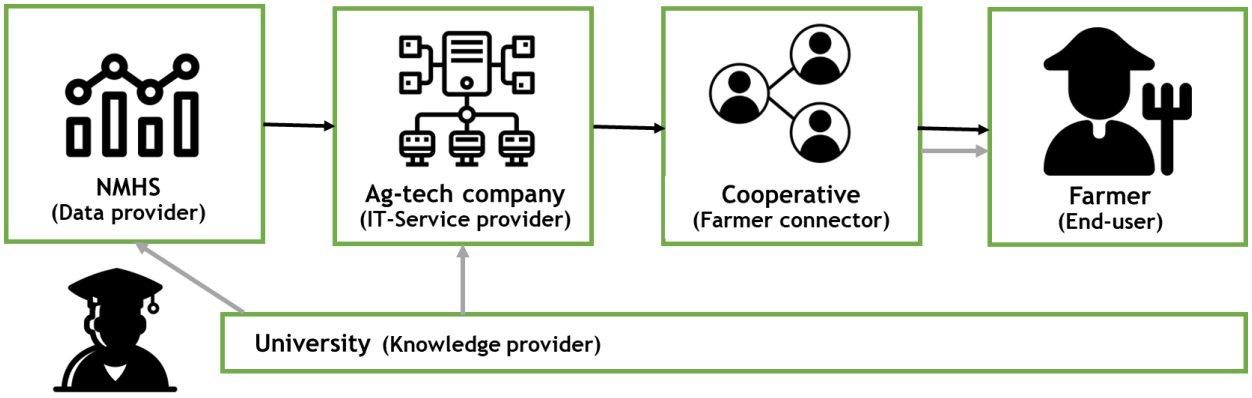


Figure 1: An example of a specific chain of partners for delivering a customized agro-weather service to small-scale farmers. The chain contains a variety of roles: the data provider, the IT service provider, the farmer connector, the end-user and the knowledge provider. The respective roles are taken on by the NMHS, the ag-tech company, the cooperative, the farmer and/or the university. In this case, the knowledge provider is not part of the partner chain for operational service delivery (indicated by the black arrows). Examples of capacity-building activities are indicated by the grey arrows. This partner chain model derives from the HydroNET partner chain model (Rain4Africa, 2020).

Many NMHS in low-income countries are insufficiently equipped to provide good-quality weather services or to take on the role foreseen for them in the agromet or hydromet value chain. They face budgetary issues and lack, for example, the infrastructure capacity needed to operate their services and maintain their ground-station network, to run NWP models and to develop services. This is a huge problem because demand for improved hydrological and meteorological services is increasing across the globe, particularly in the countries most vulnerable to the effects of climate change. This creates opportunities for international private weather service providers. But without a strongly positioned NMHS, there is a serious risk that the continuity of countries' public weather forecasting and alerting services will be jeopardized by the private sector.

Over the past few years, institutes such as the World Meteorological Organization (WMO) and the World Bank have conducted many studies and programmes aimed at improving the position of NMHS and explaining how they can benefit from, instead of being threatened by, the growing private sector (Rogers & Tsirkunov, 2013) (Rogers, et al., 2019) (WMO, 2014). Focusing on the value chain as a whole is recognized as being potentially the most effective route to follow (GFDRR, 2019) (Rogers & Tsirkunov, 2013). Supporting and enabling the different public sector parties – such as universities, research institutes and the NMHS – to cooperate and define their respective roles will create additional capacity for providing reliable, high-quality services. The same applies to the cooperation between public and private parties, where it is essential for roles to be clearly separated and for an enabling legal framework to be in place. The examples set out below show why a value chain approach makes more sense than focusing solely on the NMHS:

- NMHS staff need to have the right education and capacity to develop their services. A tailored educational programme at a university is essential for delivering well-trained NMHS employees, both now and in the future;
- An NMHS needs costly computational infrastructure to run its NWP models. But operating these computers requires a well-functioning and reliable power and internet supply;

- Although the NMHS issues the official weather warnings through their website and possibly a public app, a privately owned app, dedicated to farm-decision support, that distributes these warnings increases the reach and, therefore, the impact of these warnings.

Although there is no single answer to the question of how to ensure a value chain for agro-meteorological services functions optimally, we outline in the next and final section of this chapter what a weather service tailored to small-scale farmers could look like within this framework.

## Weather services tailored to small-scale agriculture

How can we benefit from advances in weather services so as to address the challenges of our time and secure food production for an increasing population, while also adapting to and mitigating climate change? What does the concept of the agromet value chain mean in practice for the developing of services for farmers?

Compared, for example, to the healthcare sector, the agricultural sector is highly fragmented and has many different stakeholders, including farmers, traders, buyers, governments, input suppliers, service providers, cooperatives, etc. Cooperation and a clear definition of the respective roles are essential when developing a weather service within this ecosystem (AGRA, 2017) (Carter, Steynor, Vincent, Visman, & Lund Waagsaether, 2019).

The objective of agricultural meteorology is to assist farmers to prepare themselves by providing them with knowledge tailored to their agro-meteorological practices (WMO, 2012). Traditionally, NMHS provide agro-meteorological bulletins containing outlooks for the coming season. Farmers have access to weather news on national radio and television, which often informs them of the upcoming weather in their region, but not necessarily in their village or farm, and not necessarily focusing on agricultural applications. Many regions also provide farmer-specific radio broadcasts. But while extension officers and development agents support farmers in their decision-making, these officers and agents are not available operationally.

Many tailored services making use of new communication technologies have been developed in recent years, with localized weather forecasting by mobile phone having been assessed by farmers to be one of the most highly valued advisory services (Mercy Corps Agrifin, 2019) (GSMA, 2016). However, many such services were developed as part of a donor-funded project, and not all of them have proved to be equally sustainable in the longer term. There are various reasons why such services may be terminated after the project ends, including the absence of an effective business model, challenges in scaling, and insufficient adoption by end-users (Amick, et al., 2019) (Siewertsen, Waruingi, & Muriithi, 2016). However, some of these initiatives are now close to developing successful business models for the services they provide, and it is essential to consider the position of the NMHS in this process.

*I believe digitalization is a big intervention, which needs the policymakers' attention to reach farmers.*

Esayas Lemma Hayi, Director of Crop Development Directorate, Ministry of Agriculture, Ethiopia

Here, we adopt the concept of the agromet value chain to outline a successful partnership for delivering a mobile forecasting service to small-scale farmers. This value chain comprises:

- The NMHS as the mandated organization for meteorological services, and the provider of observation data, numerical weather predictions, forecasts and official warnings;
- A service provider: a party who develops the service tailored to farmers and is responsible for the service's financial and institutional sustainability and for its quality. In the case of a public service, this role can be taken on by a wide range of organizations (e.g. the NMHS or the Ministry of Agriculture). In the case of a private service or a public-private partnership, it can be taken on by a non-governmental organization, a private weather service provider, an agri-service platform or a specialized ICT partner for hosting, application development, user database management or text message dissemination;
- An end-user connector who is in contact with the farmers, knows their needs and is involved in farmers' registration, education and capacity development;
- A university or specialized agricultural research organization for further research and development, knowledge provision and institutional capacity-building;
- Eventually: mobile network operators for disseminating messages, data aggregation platforms, ICT service providers, a partner for monitoring and evaluating the service, other knowledge providers, etc;
- Eventually: external paying clients, such as input suppliers who use the service to generate additional customer loyalty, or insurers or financial institutions who use it to reduce their portfolio risks.

Capacity-building should play an essential role in the activities of all the parties involved. This applies both at an institutional level (i.e. at the university, NMHS and service provider) and at an end-user level (for training farmers to interpret the information provided to them on their mobile phones).

We argue that taking all these different actors in the value chain into account is the best way to increase the chances of developing a sustainable and valuable service. Building trust and confidence with end-users and cooperating with them are key. And so, too, are providing location-specific and reliable forecasts and communicating on forecasting uncertainties. Information and technology should also be tailored to user needs by being in the local language and disseminated to users via appropriate communication channels. Information and technology should preferably also integrate local indigenous knowledge so as to further improve quality at a local level (Nyadzi, 2020) (Masinde & Thothela, 2019).

In the next chapter we describe the farmer-tailored weather service that was developed in Ethiopia in a chain of public and private partners, as shown in figure 1.

# MOBILE WEATHER SERVICE IN ETHIOPIA

Farmers in the sesame production zone in Ethiopia (Amhara and Tigray) have to deal with increasingly unpredictable weather conditions. Irregular rainfall during the growing season significantly impacts on their yields. Furthermore, heavy rainfall and wind gusts can reduce annual yields towards the end of the season, when the sesame is drying in the fields after harvest (see figure 5 in the next chapter). Being able to deal with these conditions more effectively can increase yields and reduce post-harvest losses. Nowadays most farmers have a mobile phone and can be reached by phone and text messages, even though 40% of the people in these areas are illiterate.


Figure 2: Mobile weather forecast in Amharic

Starting in 2017, with 3500 farmers, a targeted group of sesame farmers, *woreda*[2] experts and agricultural researchers have been sent location-specific weather forecasting information twice a week in the form of a text message (SMS). By 2020, the numbers of people benefiting from using the service had increased to almost 10,000. The information is provided in the local languages (Amharic or Tigrinya). Farmers are registered for the service by field support staff and agronomists from the implementation partner, Sesame Business Network. The SMS contains information on rain probability and amount; on the average, maximum and minimum temperatures and on wind speeds for the next three days; and on the likelihood of rainfall for up to seven days ahead.

A chain of partners and activities is in place to disseminate the localized forecasts. This partnership optimally covers the different roles and activities in the "agromet value chain", as described in chapter 1. IT infrastructure has been developed to run the NWP model output, to translate this output into actionable, localized messages to farmers and to disseminate these messages to the farmers' phones by SMS. The partnership focused on capacity development and extensively evaluated the usefulness of the information provided to end-users, as well as assessing the performance of the forecasts across the region.

[2] A *woreda* is an indication of a district (a third-level administrative division) in Ethiopia.

## Sesame production in Ethiopia

For Ethiopia, sesame is one of the most important oil crops in terms of area coverage and foreign currency earnings. Seventy per cent of the sesame exported is produced in the north-west of the country (Amhara and Tigray). More than 550,000 ha of land is covered by sesame and around 160,000 households are involved in sesame production. The majority of the farmers are smallholder farmers, with average landholdings of 3.4 ha. However, a considerable amount of the sesame is cultivated by large-scale (investor) farmers.

Each year, more than 500,000 labourers move to the sesame-growing areas from other parts of Ethiopia to perform various agricultural activities, such as land clearing, weeding, harvesting and threshing. Sorghum, soybean and cotton are grown on a large scale in rotation with sesame.

The sesame sector is facing various challenges, such as outdated production technology, the lack of availability of quality seeds, pest and disease outbreaks, shortage of finance and anomalies in weather conditions.

Sesame is sown from early June to mid-July. It is matured for 90-120 days, depending on the variety. The sesame is harvested when farmers feel it has matured. They consider the crop ready for harvest when the lower pods start cracking and easily release seed, when the colour of the plant changes from green to lemon yellow, or when the leaves shade and all the stems and branches darken or become dry. When the crop has matured, the sesame stalks are cut with a sickle and put together in *hilla* (i.e. stacks of 400-500 stems) to dry for more than two weeks in the field. During this drying period, the sesame is vulnerable to weather conditions such as strong winds or heavy rain.

# The partnership in Ethiopia

The partnership consists of five complementary parties with the following roles:

- Benefit-Sesame Business Network (SBN) aims to develop a more competitive, sustainable and inclusive sesame sector in Ethiopia and to improve farmers' income. This network supports the sector in innovation and in capacity and policy development. Its role in the current consortium is as facilitator, last-mile implementer, evaluator and trainer;
- The National Meteorological Agency of Ethiopia (NMA), as the mandated institution for disseminating weather forecasts in Ethiopia, delivers the weather forecasts in this partnership and is involved in quality control of forecasts;
- Weather Impact (WI), a private-sector weather company from the Netherlands, develops tailored weather and climate solutions for the agricultural sector. WI has a role as a service provider or broker, in developing relationships to establish a service in cooperation with the other stakeholders, in providing technical expertise and in supporting capacity development of NMA staff through workshops;
- Apposit, a software development company in Ethiopia, is responsible for the ICT technology used to disseminate the forecasting messages to farmers' mobile phones;
- Wageningen Environmental Research, a well-known research institute that is part of Wageningen University, has supported the partnership since the start in 2016, initially as a leading partner and later as a knowledge provider and adviser.

In 2019 and 2020, the project and partnership were facilitated by SBN, a bilateral partnership set up between the Netherlands and Ethiopia to strengthen sustainable agricultural production, markets and trade and to create an enabling institutional environment for the agricultural sector. The partnership was originally developed and piloted in 2016-2018 under the scope of the CommonSense project, a "Geodata 4 Agriculture and Water" project funded by the Dutch Ministry of Foreign Affairs via the Netherlands Space Office.

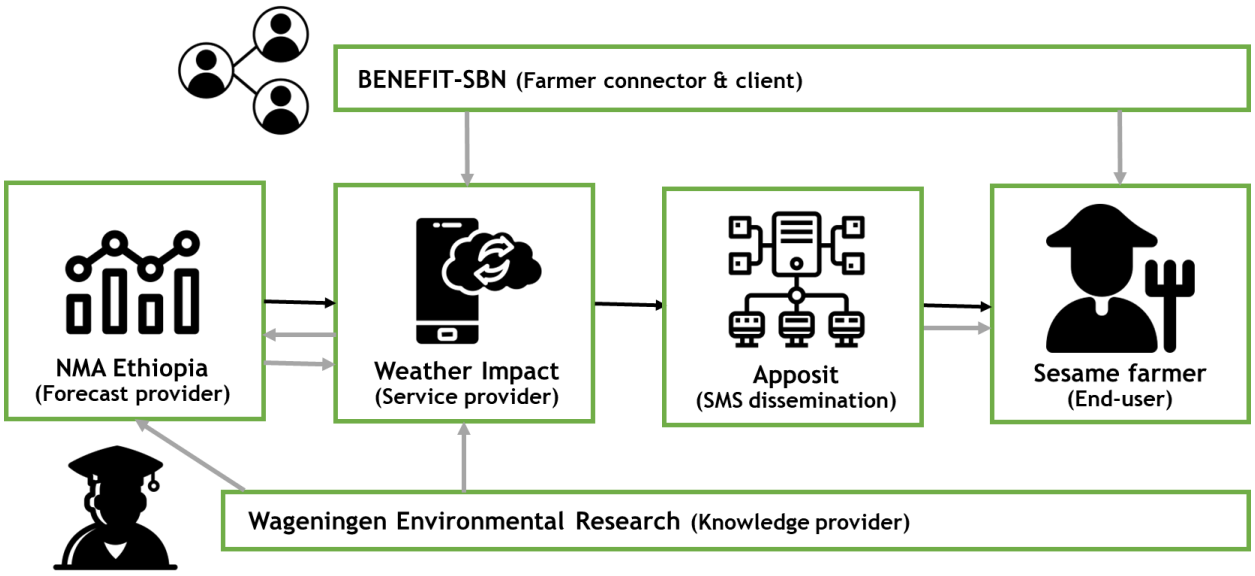


Figure 3: Partner chain for weather services provided to Ethiopian sesame farmers (analogous to figure 1). Operational service delivery is indicated by the black arrows, while examples of capacity-building activities / knowledge transfers are indicated by the grey arrows.

# Monitoring, evaluation and validation

User satisfaction assessments and feedbacks help to improve the content, quality, accuracy and timeliness of information and to make it more actionable, usable and understandable for farmers. SBN agricultural professionals regularly interview farmers on the usefulness and accuracy of the service. The continual feedback and communications between the service providers (Weather Impact and NMA) and the professionals in the sesame zone have improved the accuracy and specificity of the forecasts (Mikser, Fissha, Aniley, Tsegaye, & Bijen, 2017).

A second evaluation pillar involved validating the performance of the weather model by comparing the forecasts to >100 ground-based weather stations from the NMA. This study, which was performed by NMA experts in collaboration with experts from Weather Impact, focused on all the major areas in Ethiopia where the NMA has weather stations, and looked at the accuracy of the rainfall likelihood and amount and the minimum and maximum temperatures. The exciting outcome of this study was that not only were the forecasts found to be sufficiently reliable (forecasting of upcoming rain events: 80-90% accurate (Admasu, et al., 2018)), but users were also even more positive about the overall accuracy of the forecasts than in the ground-station comparison.

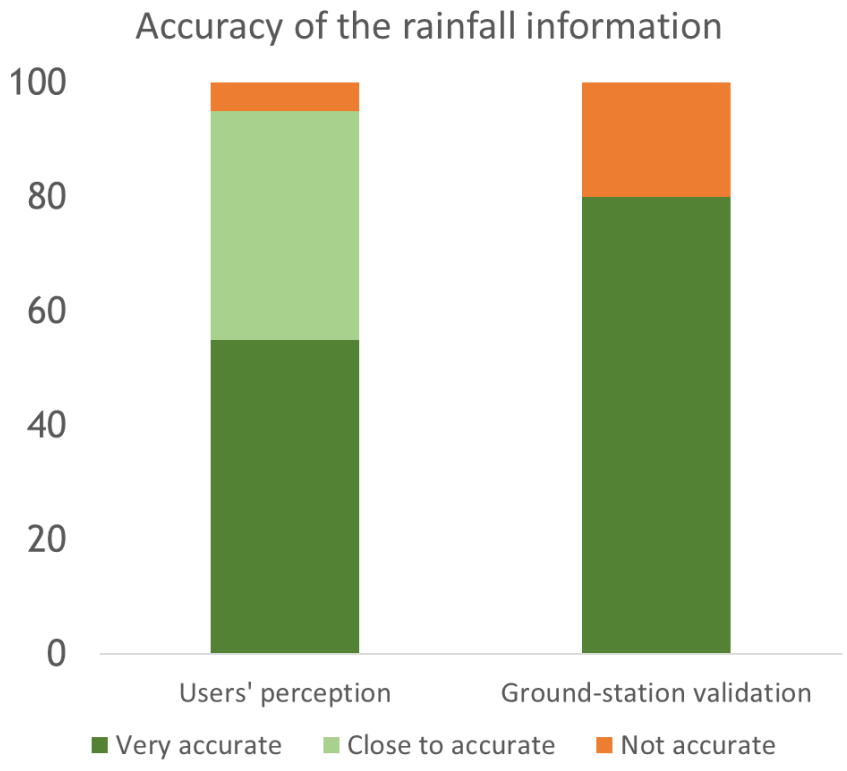


Figure 4: Evaluation of the quality of the forecasts based on users' evaluation (left bar) and ground-station measurements (right bar).

# Capacity development

Farmer field schools and capacity development workshops have improved farmers' interpretation and understanding of weather forecasting information and its delivery in the community. So far, 22 agricultural experts and researchers have been trained to use rain-gauge installations and data recordings and to interpret weather forecasts. More than 200 development agents and farmers have been trained as "Trainers of Trainers" (ToT) for interpreting weather forecasts. This group, in turn, has trained farmers in each *kebele*.[3] These ToT workshops and farmer field schools were guided and organized by an interdisciplinary team of SBN and NMA staff from local branch offices in North-West Ethiopia (Bahir Dar, Tigray). The NMA meteorologist contributed meteorological knowledge on forecasting and communicating on forecast uncertainty and confidence. The SBN agronomist provided support in the form of practical knowledge on farmer needs, as well as giving practical insights into how to interpret the forecasting messages and make weather-wise farm management decisions based on the information provided.

Workshops for NMA staff members have also been organized on a regular basis to enhance their knowledge and skills in the field of data analysis using the programming language Python, in developing crop advisory services and in data-quality control. These workshops were given by Wageningen University and Weather Impact experts with the aim of institutionalizing partner chain service delivery within NMA.

*"The training is interesting and important for our daily work. Most of us are highly interested in Python programming as we can use it for different applications, like meteorological advisory dissemination."*

**Dereba Muleta, Acting Director – Meteorological Education and Training, National Meteorological Agency of Ethiopia.**

[3] Smallest administrative unit in Ethiopia; village, neighbourhood level.

## User testimonial from Mr Yelale Amebachew

*"I shared the weather forecast with my colleagues during the coffee ceremony and other social gatherings. Some thought that I had intervened in God's work. Some laughed at me and others asked why only I get the SMS. What I observed is that the weather forecast is very useful to farmers. In previous years, the only source of information about weather was what I heard on television, but now I get the daily forecast on my phone. I believe the information."*

Mr Yelale is one of the farmers in Tachi Aremachiho *woreda*, Kokora *kebele*, who receives the SMS weather forecasts. He lives with his wife and two children in the *kebele* and engages in both crop and livestock production. In the production season he planted 1 ha of sesame, 1 ha of sorghum, 0.25 ha of teff and 0.75 ha of finger millet.

He used the weather forecasting information to determine the planting date of sesame, to put the *hilla* (harvested sesame) under plastic sheets and to protect the teff and millet piles from rainfall and wind. Mr Yelale said that, around May, he wanted to sow sesame but got a weather forecast SMS that indicated there would be no rain in the coming days. He decided to change the sowing date until the forecasts said there would be rain again. When he received a rain forecast, he decided to sow the sesame, and the first day he planted, the rain came and the seed was able to germinate very well. Had it not rained, the seed would have been eaten by birds and termite or it would have dried and germinated poorly.

# LESSONS LEARNED

**1. A twice-weekly, localized weather forecast by mobile phone can make an essential difference to farmers in their day-to-day farm management**.
The service has demonstrated that location-specific delivery of weather forecasts support farmers in their decision making. User evaluations provide practical examples how the forecasts help sesame farmers improving their production and reducing post-harvest losses. The weather forecasts are used to decide the right time for planting, fertilizer top-dressing, weeding and harvesting. More and more farmers now have mobile phones, and this provides good opportunities to digitalize the sector.

Weather forecast SMS messages have to be in the local language so that farmers can easily understand them. The date and period of the forecast, as well as the location to which it applies, have to be clearly indicated. The evaluations found that the units of measurement (mm and $^{0}$C) included in the weather forecasting information could be rather difficult for farmers to understand, but frequent back-and-forth workshops and communications improved both the contents and the presentation of the forecasts. If illiterate farmers (40% in the sesame zone) are to be reached, it is important to involve family members who have had the chance to be enrolled in education. Collaboration with rural schools, teachers and students – for example, by teaching the topic in geography classes – is expected to increase the reach and improve the interpreting and understanding of weather forecasting information and its delivery in the community.

Weather forecasts delivered by SMS should start as early as possible in the season and continue until all the crops have been harvested and bagged. The regularity and accuracy of the forecasts create trust among recipient farmers, who have increasingly used the weather forecasts to plan and adjust their farming activities.

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*We learned that, to be sustainable, a service of this type needs patience, determination and a collaborative attitude. We can all learn from each other and build a partnership that creates value for us all.*

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Tomaso Ceccarelli, Senior Researcher – Global Food Security, Wageningen Environmental Research, and Project Leader for the Geodata 4 Agriculture and Water project 'CommonSense'


Figure 5: Wind damage (visible on this picture as the white sesame seeds on the ground) to sesame *hilla*. After harvest, the sesame is laid out to dry in the fields, where strong winds and rain can cause huge yield losses. Photo by SBN.

**2. Institutionalization of the service delivery within the National Meteorological Agency and cooperation with other government bodies is necessary for long-term continuation of the services.**

The only way to achieve sustainable results is through collaboration with institutions mandated for weather forecasting and with agronomic services. In Ethiopia, like in many African countries, the National Meteorological Agency is mandated to provide weather services in the country. By law, the NMA's consent and cooperation are required in order to develop operational weather and climate service in the country. Institutionalization of the service in this agency is thus essential if the service is to be continued in the long term. This can be achieved by continuing, improving and developing the partner chain that has been built up over the past five years. Other actors, such as Ethiotelecom, the Ministry of Agriculture and the Ethiopian Agriculture Transformation Agency (ATA, part of the ministry), should also be actively involved in future developments of the service. Ethiotelecom can play an essential role in ensuring the service delivery is reliable. This is important as delivery was challenged during the communication lockdowns in 2020. The Ministry of Agriculture and its extension services have a role to play in the service delivery, in upscaling and in institutionalizing operational, weather-based services and translating them into actionable advice for farms. This goes hand-in-hand with ATA's mission to help accelerate the growth and transformation of Ethiopia's agriculture sector, focusing on smallholder farmers across the country. Further institutionalization and cooperation between all these different actors requires their respective roles to be defined more precisely and probably also improvements in the policy frameworks for the service delivery value chain.

**3. High-quality, high-quantity local weather data are necessary for validating weather forecasts in Ethiopia's various climatic zones**.

To be useful as decision support for farmers, a weather service needs to be reliable. Local ground validations and evaluations of the forecasts provided are at the core of our work. This pilot used a combination of NMA's forecasting model and a global forecasting model (the model used by the European Centre for Medium-Range Weather Forecasts, or ECMWF). Ethiopia has very diverse climatic conditions, and not much was previously known about the ECMWF model's usefulness at a local farmer level in Ethiopia. To evaluate and validate the model's performance, it is therefore essential to have access to reliable weather data covering Ethiopia's different climatic zones and with a sufficient historical archive. The NMA is the primary provider of these data in Ethiopia. A ground-truthing validation study of the ECMWF short-term forecasts was conducted by NMA and Weather Impact. The quality of these forecasts was compared with >100 NMA ground stations to check their accuracy in forecasting rainfall events over the next 7 days. The forecasts for rainfall over the next 3 days were >80% accurate. Further downscaling of the forecasts may result in improved accuracy (Admasu, et al., 2018). The current service delivery uses NMA's high-resolution WRF model. For the future, the partnership envisages further improvements in these forecasts by using the ECMWF model as the boundary conditions, and further integrating ensemble[4] modelling output into the service delivery to farmers.

**4. Global models and cloud IT infrastructure solutions enable efficient delivery of high-quality services.**

National meteorological services are the primary provider of weather and climate information in a country. In this pilot, we recognized the need for long-term solutions and consequently the need for long-term empowerment of the NMA. Although many global or regional centres – e.g. WMO, IRI-ENACTS, Copernicus and NCEP-NOAA – have data, interfaces and models to support their colleagues in the Global South, insufficient use has so far been made of these opportunities. We discovered that there are opportunities to make the best use of both worlds. When developing capacity at NMA, there should be a particular focus on high-quality tools, solutions, interfaces and services that are already available. If, for example, the NMA can access the ECMWF ensemble forecasting model, the NMA can use this global model as the boundary conditions for its own local numerical model and develop downscaled local ensemble forecasts. This is a quicker and more cost-efficient solution than trying to operate ensemble forecasting technology within the NMA itself.

[4] A forecasting technique that is essential for making weather risk estimates, but requires costly IT infrastructure (supercomputer) and advanced knowledge of running and initiating such models.

**5. Capacity-building and development are essential for establishing a successful service**

The provision of weather forecasting information should be accompanied by capacity-building so that farmers know how to use this information for farm management decisions. Practical workshops and field schools with agricultural professionals, community school teachers and farmers (via a "training of trainers" method) ensure that the weather information in the SMS message is clearly understood. Evaluations with farmers, as well as contact moments at farmer field schools, were used to support an end-user-focused design of the service and to ensure the beneficiaries' active involvement in improving the services.

Additionally, a series of capacity development workshops were given for the relevant NMA staff. These workshops focused on acquiring the skills and capacity required to develop NWP model output into a service that is actionable for farmers, such as Python programming, data analysis, and quality control and partnership models. The next step for developing services in cooperation with our partners is to focus on capacity development of NMA staff with the skills required to access the globally available data (lesson 4) and to use cloud IT solutions, APIs and web interfaces.

**6. Public and private partners can co-create to develop the business case for weather and climate data**

Another point of attention is the financing of tailored weather forecasting services. Although this pilot was largely based on project funding, modalities for sustainable funding are of fundamental importance. The partnership explored several ways of developing sustainable income for the service. It is argued that weather forecasting is a public task of the NMA, and that weather forecasts should be available to farmers for free. In the case of commercial commodities such as sesame, however, innovative payment systems could be an option, e.g. a service delivery linked to or combined with other services such as credit provision or input supplies, or a system where farmers pay for the received services when selling their crops via their cooperative.

Translating the weather forecasting information into farm management decisions and field level actions is an important challenge, and one that needs to be properly considered. Other parties, such as the Ministry of Agriculture and the cooperatives, should therefore be involved in the agro-meteorological value chain. Mobile digital services offer the potential to develop extension services in a much more scalable manner. This pilot can serve as a blueprint for developing digital extension services in other regions and for other crops or commodities.

Building long-lasting chains with local and international partners to empower the NMA in providing good-quality weather and climate data for the country will also support service delivery to sectors other than agriculture, such as the water, energy, infrastructure and finance sectors.

# FUTURE SERVICES FOR SMALL-SCALE FARMERS

Owing to increased mobile phone adoption, we expect to witness a further increase in weather services for small-scale farmers in Africa in the next few years. This exciting prospect requires large numbers of dedicated stakeholders if services are to be developed in a sustainable manner. By developing a strong agromet value chain, public and private partners can cooperate to establish services tailored to the agricultural sector and eventually to all the other sectors – such as the energy, finance and water sectors – that need weather and climate information in their day-to-day operations.

Our aim in this article is to share the lessons we learned in Ethiopia. We believe that this experience has a wider application and needs to be shared for use in initiatives in other regions and countries. Adapting to climate change is a local challenge that is presenting itself all around the world. By sharing our experience we hope to inspire current and potential new partners to develop local weather information services in sustainable partnership with the National Meteorological and Hydrological Services.

Our partnership and services in Ethiopia have proved to be successful over the past five years, even in the turbulent times seen in Ethiopian politics in 2017-2020 (Aljazeera - ethiopia news, n.d.) and during the covid-19 pandemic. This ongoing partnership has created a basis of trust and ambition. We are now aiming to increase our reach to ten or one hundred times as many farmers as we are currently reaching. We are dedicated to improving the NMA's forecasting skills and capacity and to further institutionalizing the service within the agency and for other stakeholders in the Ethiopian agricultural sector. We also plan to reach out to other public partners such as universities to continue researching the effectiveness of our services for supporting farmers and to continue building the partnership's capacity. We are working with Ethiopian institutions to build for the future, focusing on achieving long-term change. To establish these goals we need to increase our engagement with other public and private partners and are therefore calling out to partners who support our mission.

What will the future bring? We recognize three major areas for further developing the services:

1. Specific farm advice is a logical follow-on for combining with and expanding general weather forecasting services. This advice could include planting advice based on monitored and forecasted rainfall, or spraying advice indicating when the weather is favourable for the development of fungal diseases. In this way, the hydromet value chain can evolve into an agro-meteorological value chain that includes other stakeholders from the agricultural sector such as the Ministry of Agriculture, input suppliers and cooperatives.
2. Continuing improvements in the forecasts themselves, downscaling the services to the extent possible and maintaining the highest possible forecasting skill. The service should evolve into

being a true co-creation *with* farmers instead of *for* farmers. Integration of indigenous knowledge and crowdsourcing of local observations on weather will further support the downscaling, adoption and usefulness of the services. In the longer term, the crowdsourced datasets retrieved could even support further weather model refinement and model initiation or validation. This could even be expanded to include agronomic observations or data – such as data on pest occurrence, planting dates, crops grown – to further improve the delivery of tailored services at a local farm level.

3. A sustainable service that farmers can trust is possible only if there is a sustainable business model in place to ensure the service's long-term continuation. Although the value for farmers is clear, there are many reasons why the model for a tailored, personalized weather service for small-scale farmers is still under construction. All the players in the "ecosystem" – the public bodies, the private actors and the research organizations – are exploring their respective roles. Further development of the market, and particularly development of digital and other services for small-scale farmers – such as insurance, credit services, input supplies or soil analysis – will support a thriving ecosystem in which weather services will be combined with other services to create an effective business model. Ideally, farmers will then be able to access high-quality agro-meteo advice adapted to local conditions, as well as accessing inexpensive credit, high-quality inputs such as seeds and fertilizer, and potentially insurance. The agro-meteo advisory product will then reduce the risks involved in the provision of these goods and financial services and create customer loyalty. Expanding the numbers of farmers subscribing to the service is essential and can be achieved by cooperating with a more diverse set of business and other partners, such as public research organisations, mobile network operators (Ethiotelecom), input suppliers, cooperatives and customers.

In summary, we see huge potential to establish long-lasting public-private partnerships for delivering the most-needed services to the world's smallest-scale food producers. Smallholder farmers are key to growing sufficient food for the global population, while climate change is the biggest challenge the world is currently facing. The market prospects for small-scale farmers entering the consumer market are dazzling. The covid-19 pandemic has emphasized the power of digital services even more. In short, ag-tech services for small-scale farming is a very exciting field to work in. And we are eager to discover the successes, partnerships and integrations that the next five years will bring.

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# Weather Impact

## About us

This article was written by Weather Impact in order to share our experience in developing partnerships set up to establish sustainable mobile weather services for small-scale farmers. Weather Impact is performing various projects in Africa aimed at improving both local food production and farmers' livelihoods. Our mission is to deliver high-quality weather and climate services to optimize global food productivity and quality and to reduce the adverse impact of climate change.
Weather Impact is based in the Netherlands and active in the field of climate and weather data science. We provide real-time data analytics to support optimal decision-making by African crop growers, producers and traders. If you are interested in cooperating with us, go to www.weatherimpact.com or contact us via info@weatherimpact.com.

**The partners in the partnership described in this article:**
The National Meteorological Agency of Ethiopia (NMA) is the mandated institution for disseminating weather forecasts in Ethiopia. www.ethiomet.gov.et/

Benefit-Sesame Business Network (SBN) aims to develop a more competitive, sustainable and inclusive sesame sector in Ethiopia and to improve farmers' income. The network supports the sector in developing innovation, capacity and policy. www.benefitethiopia.org/ and www.sbnethiopia.org/

Apposit is a software development company in Ethiopia building software to power high-impact, technology-driven businesses in Africa. www.apposit.com/

Wageningen Environmental Research, a research institute that is part of Wageningen University, has supported the partnership since its start in 2016. The Environmental Informatics Team was initially a leading partner and later involved as a knowledge provider and adviser.
www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksinstituten/Environmental-Research.htm

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